Supplemental Appendix for "Adverse outcomes during the transition to a new electronic health record"

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eMethods

A. Mortality prediction model specification

To generate predicted mortality probabilities, we used admissions in the 100% MedPAR files for the entire study period from 2011-2012. We specified the following model:

$$\text{logit}(E(Y_{i,j})) = \beta_0 + \beta_1 \text{Age}_{i,j} + \beta_2 \text{Sex}_j + \beta_3 \text{Race}_j + \beta_4 \text{OREC}_j + \beta_5 \text{CCW}_{i,j} + \beta_6 \text{DRG}_i$$

where E denotes the expected value, $Y_{i,j,}$ is the 30-day mortality of admission *i* for patient *j*, "age" represents the age of patient *j* at the time of admission *i*, "sex" is patient sex, "race" is patient race, "OREC" is the original reason for Medicare enrollment (e.g. age, disability or end-stage renal disease), "CCW" is a vector of the presence of 10 chronic conditions for patient *j* at the time of admission *i* (see Table 1 caption for more details), and "DRG" is a fixed effect for the diagnosis-related group of admission *i*. The predicted probabilities of mortality from this model were merged to each admission used in the main analysis in Table 2 and eTable2 and separated by the median into two groups: higher or lower 50^{th} percentile of mortality.

B. Marginal standardization approach for logistic regression estimates

The differences in readmission probabilities presented in Table 2 are retransformations of the β_3 coefficient in the main difference-in-differences model as described in the Methods section which represents the average adjusted change in each outcome in the post-EHR period attributable to EHR implementation relative to secular trends in nearby hospitals. Specifically, to ease interpretation, we used a simulation approach to obtain the three quantities of interest reported in Table 2: 1) the average adjusted pre-implementation outcome, 2) the average adjusted post-implementation outcome, and 3) the average change in outcome post-EHR implementation for the study hospitals versus the control hospitals. We took the following steps to estimate these quantities of interest:

1) Fit a logistic regression model predicting 30-day readmission using the specifications described in the Statistical Analysis section of the main manuscript.
2) Take 1,000 draws of coefficients from the estimated vector of coefficients, β assuming β follows a multivariate normal distribution with a mean of β and a variance-covariance matrix as estimated by the model.
3) For each draw of β coefficients, obtain the model prediction for each observation, alternately setting the post-implementation and treatment group indicators to 1 to obtain estimates for all four groups (treatment pre and post implementation and control pre and post implementation).
4) Retransform the model prediction to a probability by taking the inverse of the logistic function, $\text{logit}^{-1}(\beta X) = e^{\beta X}/(1+e^{\beta X})$
5) For each draw, calculate the mean predicted outcome across observations under each of the four scenarios (pre/post-implementation for treatment and control). To

calculate the difference-in-differences, for each draw, calculate the difference between the pre- and post-implementation in the treatment and control groups, then take the difference of those differences across each draw.

6) Estimate the average outcome for the pre/post implementation treatment group by taking the mean predicted probability of the 1,000 means in step 5 in each of the two scenarios.
7) Repeat the same procedure in step 6 for the difference-in-differences to get the average change in outcomes for treatment vs. controls. To get a 95% CI, take the 2.5^{th} and 97.5^{th} percentiles from the distribution of the 1,000 differences from step 5.

eTable 1: Characteristics of study hospitals and EHR implementation dates

Hospital Name	City	State	# of Beds	Pre Implementation Vendor	Post Implementation Vendor	Pre Implementation EHR Capability	Post Implementation EHR Capability	Go Live Date	Go Live Source
St. Catherine Hospital	East Chicago	IN	181	Unknown*	Epic	None	Comprehensive	8/1/11	[1]
Tampa General Hospital	Tampa	FL	1004	None	Epic	None	Basic	10/1/11	[2]
Ohio State University Medical Center	Columbus	OH	976	Siemens	Epic	Basic	Comprehensive	10/15/11	[3]
Aurora St. Luke's Medical Center	Milwaukee	WI	724	Cerner	Epic	Basic	Comprehensive	10/30/11	E-mail contact
Rochester General Hospital	Rochester	NY	520	Other	Epic	Basic	Comprehensive	11/5/11	[4]
Lawrence General Hospital	Lawrence	MA	189	None	McKesson	None	Basic	11/7/11	[5]
St. Vincent Hospital	Green Bay	WI	255	Allscripts	Epic	None	Comprehensive	1/29/12	[6]
Rice Memorial Hospital	Willmar	MN	184	QuadraMed	Epic	Basic	Comprehensive	2/1/12	[7]
George Washington University Hospital	Washington	DC	339	Unknown	Cerner	Basic	Basic	2/12/12	E-mail contact
Maricopa Integrated Health System	Phoenix	AZ	578	None	Epic	None	Comprehensive	3/1/12	[8]
Hurley Medical Center	Flint	MI	418	None	Epic	None	Comprehensive	3/4/12	[9]
Newark-Wayne Community Hospital	Newark	NY	270	Other	Epic	Basic	Comprehensive	5/1/12	[10]
Yuma Regional Medical Center	Yuma	AZ	333	None	Epic	None	Basic	5/1/12	[11]

University Hospitals and Health System	Jackson	MS	580	Siemens	Epic	None	Basic	6/1/12	[12]
UCSF Medical Center	San Francisco	CA	660	Unknown*	Epic	Basic	Basic	6/2/12	[13]
St. Rita's Medical Center	Lima	OH	415	Cerner	Epic	None	Comprehensive	6/18/12	[14]
Columbus Regional Hospital	Columbus	IN	234	McKesson	Cerner	None	Basic	6/24/12	[15]

*St. Catherine Hospital and UCSF indicated Epic as their vendor in the 2010 AHA IT Supplement survey, but had not yet implemented these EHRs, therefore the actual IT vendor before transition was not available.

[1] https://www.comhs.org/pr_view.asp?pr=314

[2] https://www.tgh.org/PDFs/OIP_Nov11_Final3.pdf

[3] http://www.dispatch.com/content/stories/local/2011/10/14/osu-hospital-going-paperless.html

[4] http://www.rochestergeneral.org/~/media/Images/Manually%20Migrated/RGHS%20Care%20Connect%20Patient%20Brochure.pdf

[5] http://www.lawrencegeneral.org/about-us/news-detail/lgh-launches-secure-100-electronic-medical-record/38.aspx

[6] https://www.stvincenthospital.org/Scripts/pageview_pr.asp?id=238&idpr=345

[7] http://www.wctrib.com/content/one-year-later-rice-hospital-willmar-minn-looks-back-implementation-electronic-health

[8] http://mihs.org/uploads/sites/19/board/SHCD%20BOD%20053012%20general%20session%20meeting%20minutes.pdf

[9] http://education.hurleymc.com/files/gme/uploads/2012-02_FebruaryPhysician%20Connection.pdf

[10] http://www.waynepost.com/article/20120519/News/305199982

[11] http://www.yumaregional.org/workfiles/ehr%20communication%20news%20physician%20version.pdf

[12] https://www.umc.edu/News_and_Publications/Centerview/2014-01-13-03_UMMC_gets_high_marks_for_EHR_implementation_integration_still_more_to_do.aspx

[13] http://russcucina.org/2012/06/02/t-minus-2-hours-the-technical-cutover/

[14] http://www.ehealthconnection.com/regions/mercy_st_ritas/pdfs/Publications/AnnualReports/CancerReport2012.pdf

[15] http://www.therepublic.com/view/local_story/CRH_embracing_electronic_healt_1336096826

All URL addresses above accessed on 9/30/2015.

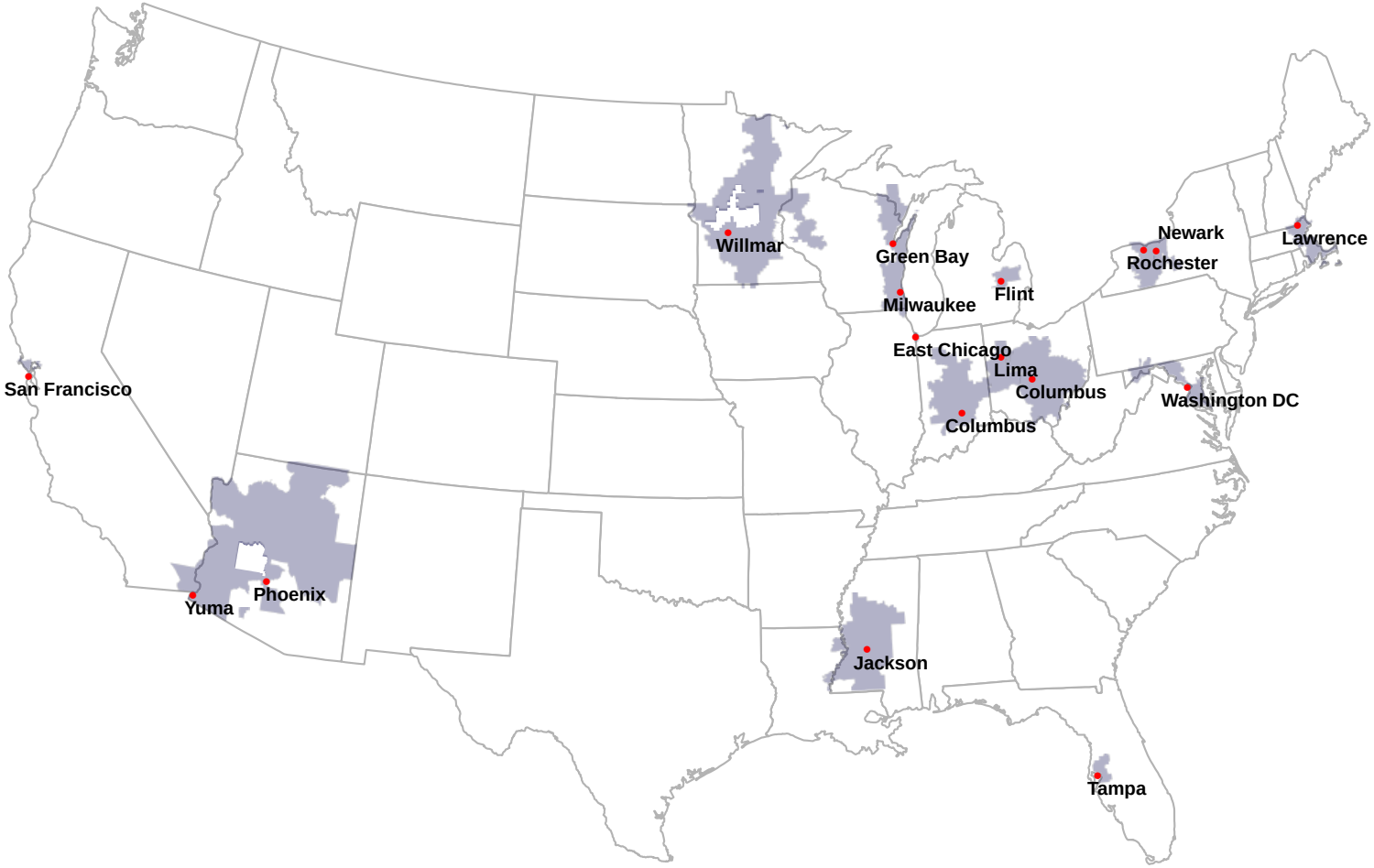
eTable 2: Sensitivity analysis of difference-in-differences analysis with hospital fixed effects

	Baseline Model*		Baseline Model + Hospital Fixed Effects**		Baseline Model for Days 90-180 After EHR Implementation***	
	Adjusted OR - Post vs. Pre-Implementation	p-value	Adjusted OR - Post vs. Pre-Implementation	p-value	Adjusted OR - Post vs. Pre-Implementation	p-value
30-Day Mortality	1.07	0.12	1.07	0.10	1.00	0.90
30-Day Readmissions	0.98	0.57	0.98	0.56	0.97	0.47
PSI-90 Rate	1.11	0.28	1.11	0.29	1.12	0.11

Abbreviations: PSI-90 (patient safety indicator 90, see Methods), odds ratio (OR), electronic health record (EHR)
* Baseline model refers to difference-in-differences model used and described in Table 2 in the main manuscript.
** Hospital fixed effects included indicators for whether an admission occurred in any of the individual study or control hospitals (n = 416).
*** Replication of the baseline model, with the post-implementation period defined as 90-180 days after implementation instead of 0-90 days after implementation.

Odds Ratios (OR) and P-values estimated from a difference-in-differences model comparing the change for each time period relative to the baseline period (1 to 90 days before implementation date) between the EHR implementation hospitals and control hospitals in the same HRR as the study hospital. All models adjusted for age, sex, race, original reason for Medicare eligibility, major diagnostic category for admission, HRR fixed effects and length of stay (for PSI-90 outcome only). All models use clustered standard errors accounting for grouping of admissions within hospitals.

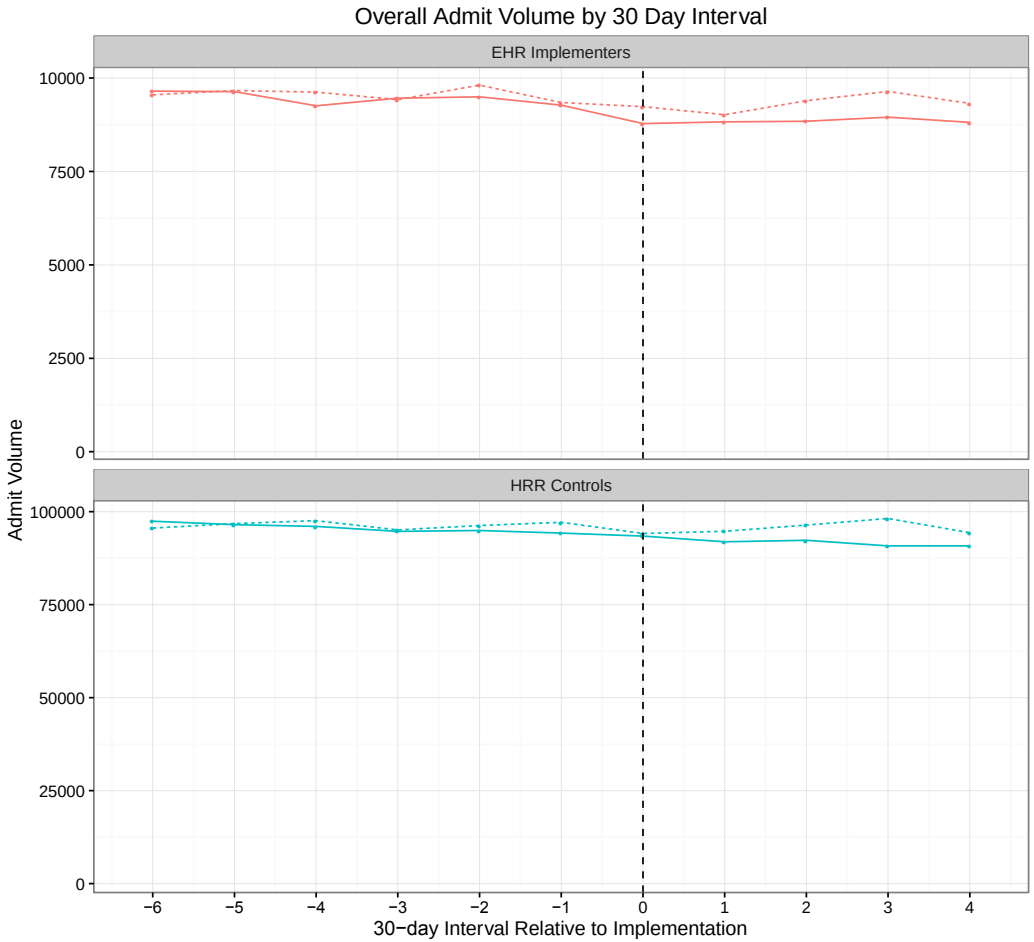
eFigure 1: Location of the study hospitals and control hospital referral regions (HRRs)



eFigure 1 shows the location of all 17 study hospitals in the analysis labeled with the city name of their location (red points). The associated hospital referral regions (HRRs) for each study hospital is shown in blue shading. For two hospitals in San Francisco and

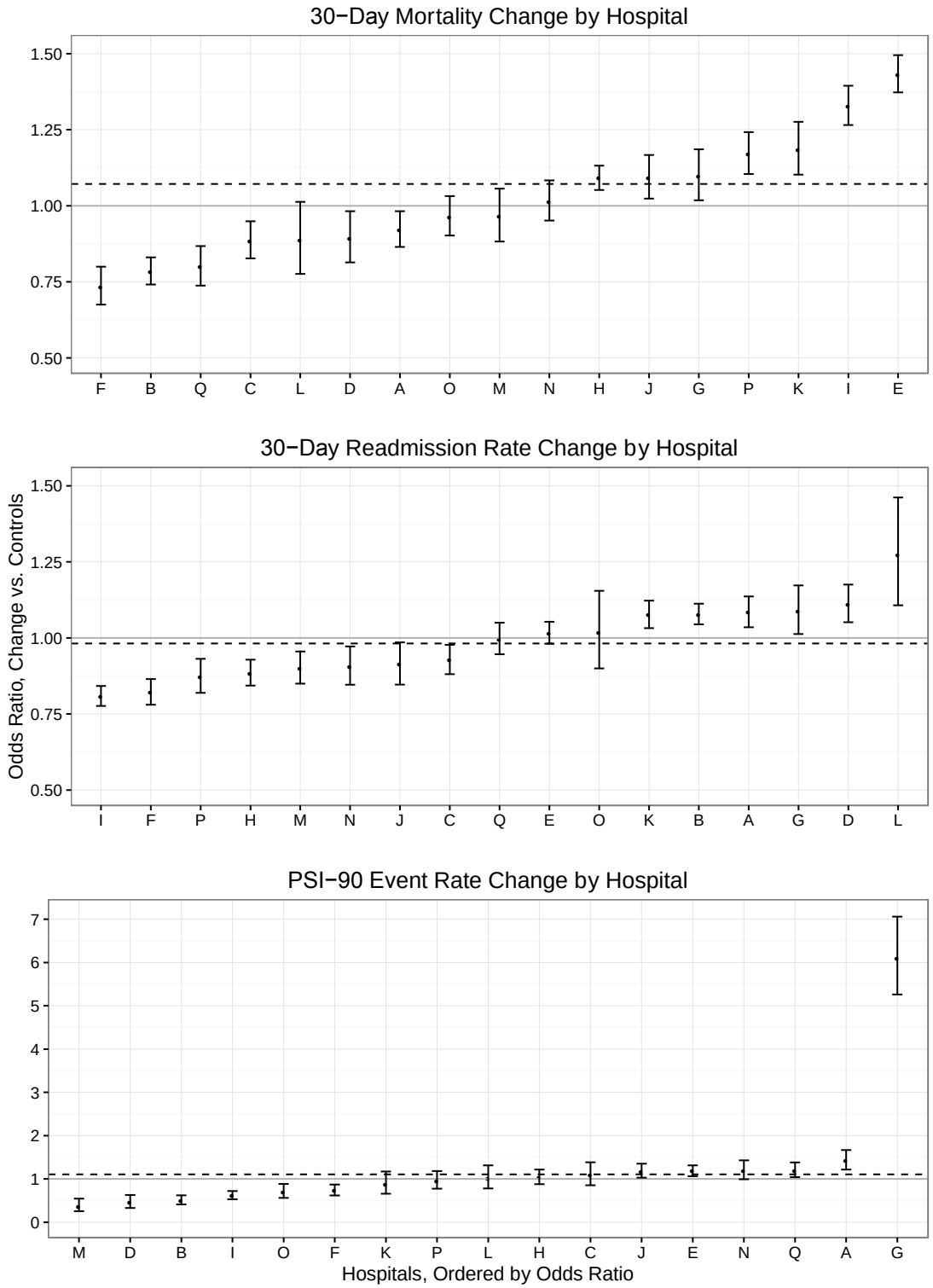
East Chicago, the HRRs are too small to distinguish because of the high population density of the associated urban areas (HRR size is determined in part by total population).

eFigure 2: Admission volume by date relative to EHR implementation, study and control hospitals



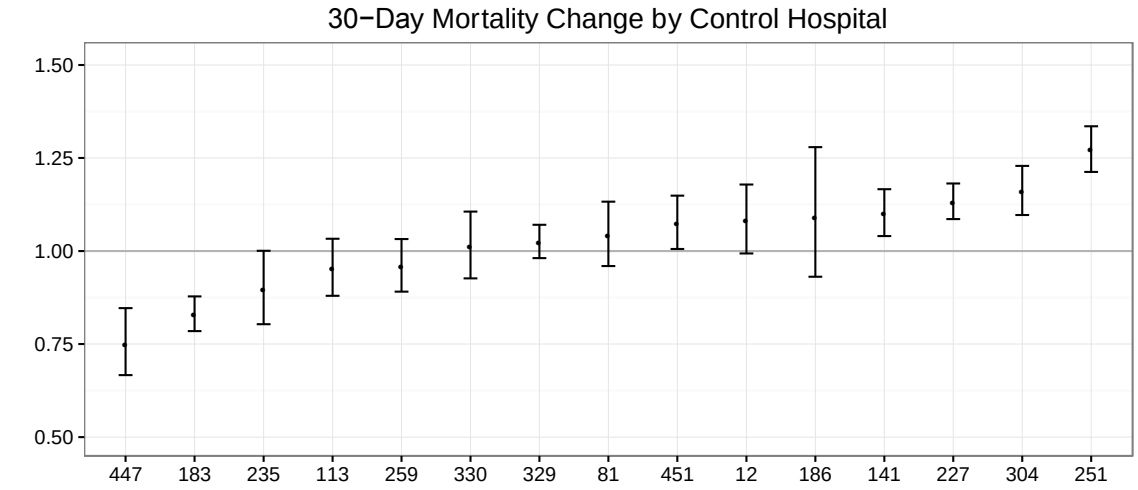
The solid line indicates admission volume for study ("EHR Implementers") and control ("HRR Controls") hospitals in 30-day intervals relative to EHR implementation. The dashed line shows admission volume on the same dates for the study and control hospitals in the year prior.

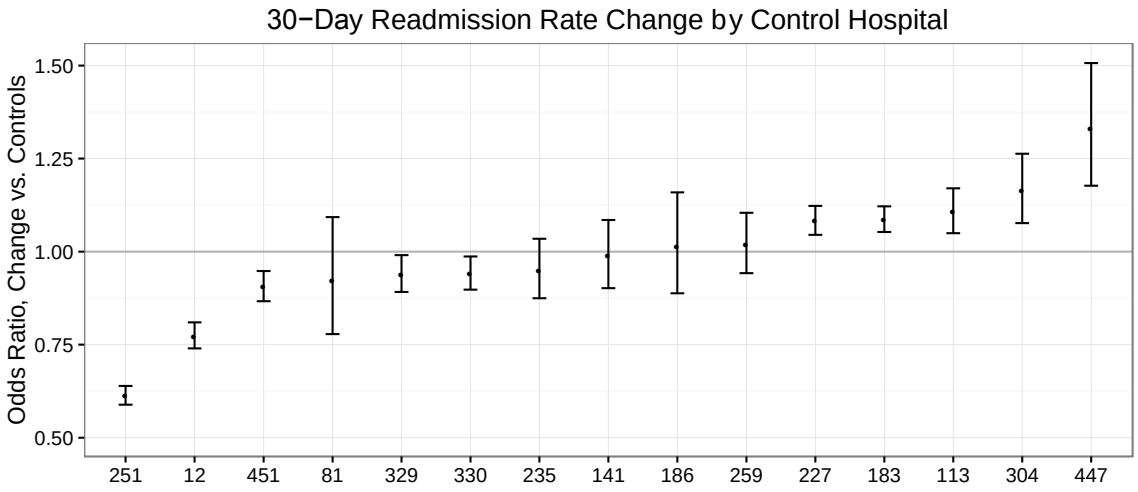
eFigure 3: Adjusted 30-Day All-Cause Mortality and Readmission Rates Associated with EHR Implementation, by Hospital

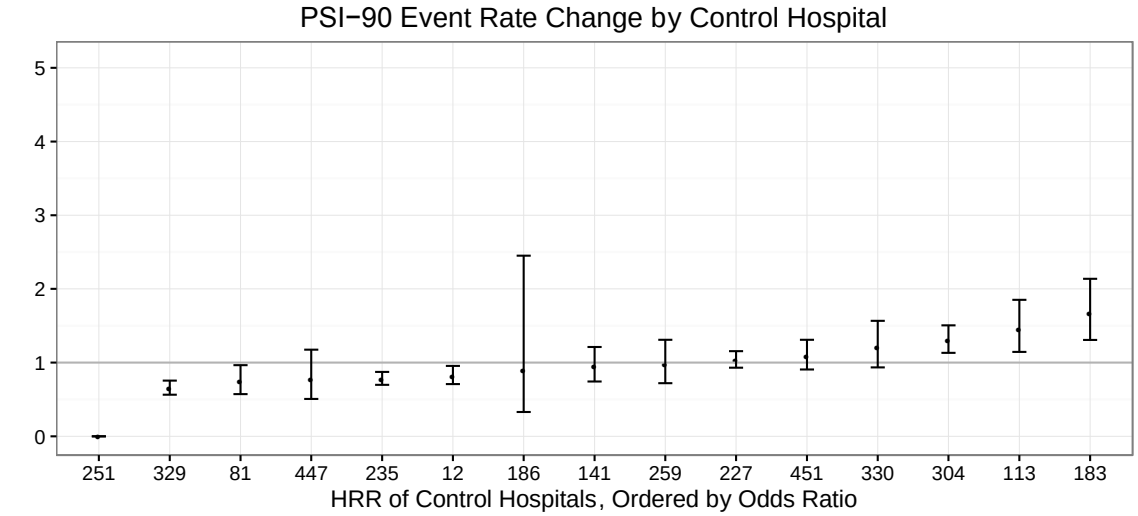


eFigure 3 shows adjusted odd ratios (OR) for the change in the rate of patient outcomes (30-day mortality, 30-day readmission rate and PSI-90 per 1,000 admissions rate) for each individual hospital versus control hospitals in the same hospital referral region in the post-EHR implementation period. All models were adjusted for patient and admission characteristics as specified in the statistical analysis section of the Methods and standard errors for 95% confidence intervals were estimated using robust variance estimators to account for clustering of admissions within hospitals. Hospitals were randomly assigned letters, which are labeled on the x-axis, ordered by the odds ratio for each outcome. The solid gray line denotes an OR of 1.0 for reference, and the dashed line indicates the aggregate OR for all study hospitals from the models used in Table 2.

eFigure 4: Adjusted 30-Day All-Cause Mortality and Readmission Rates Associated with EHR Implementation, by Control Hospitals

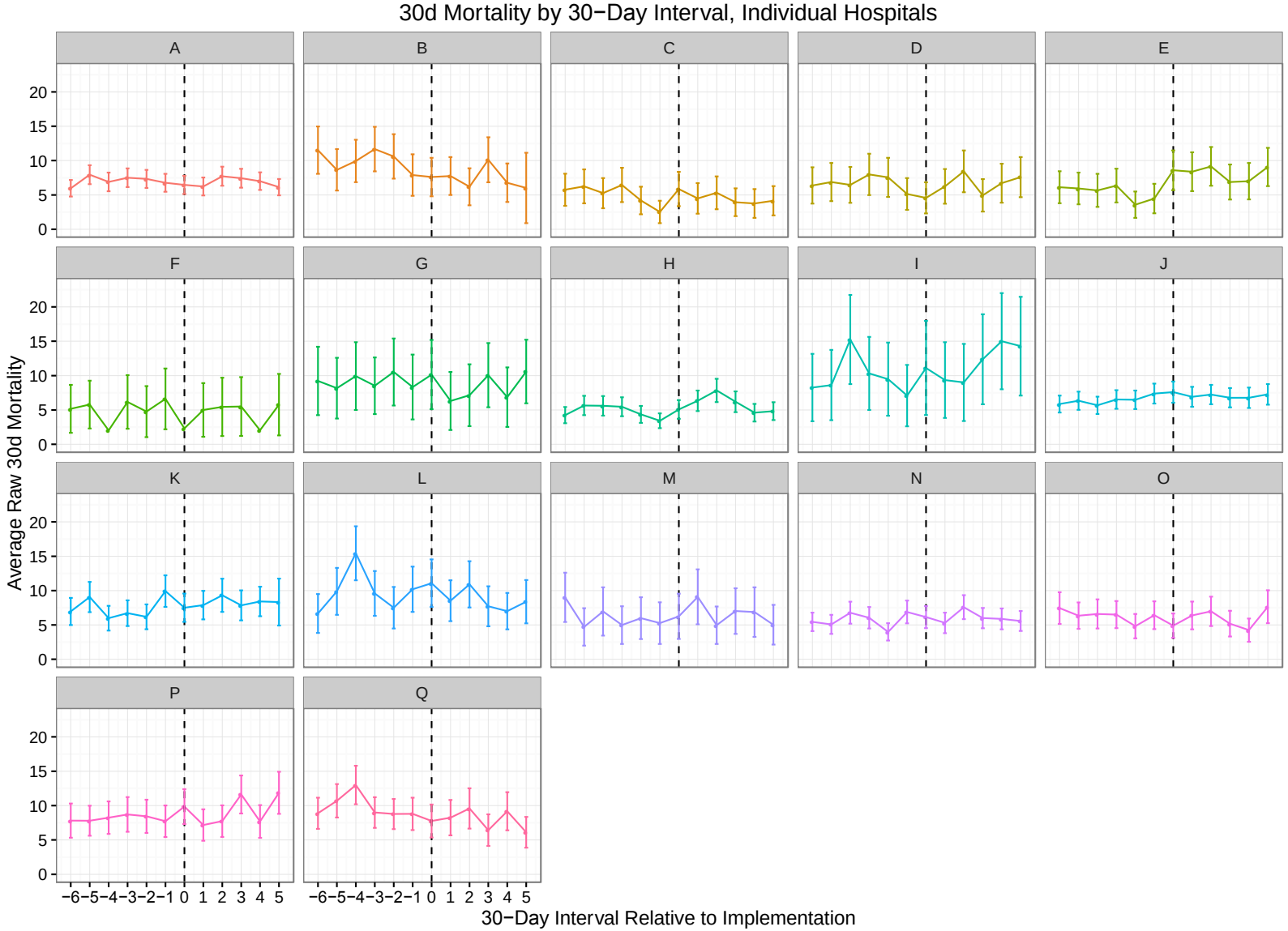






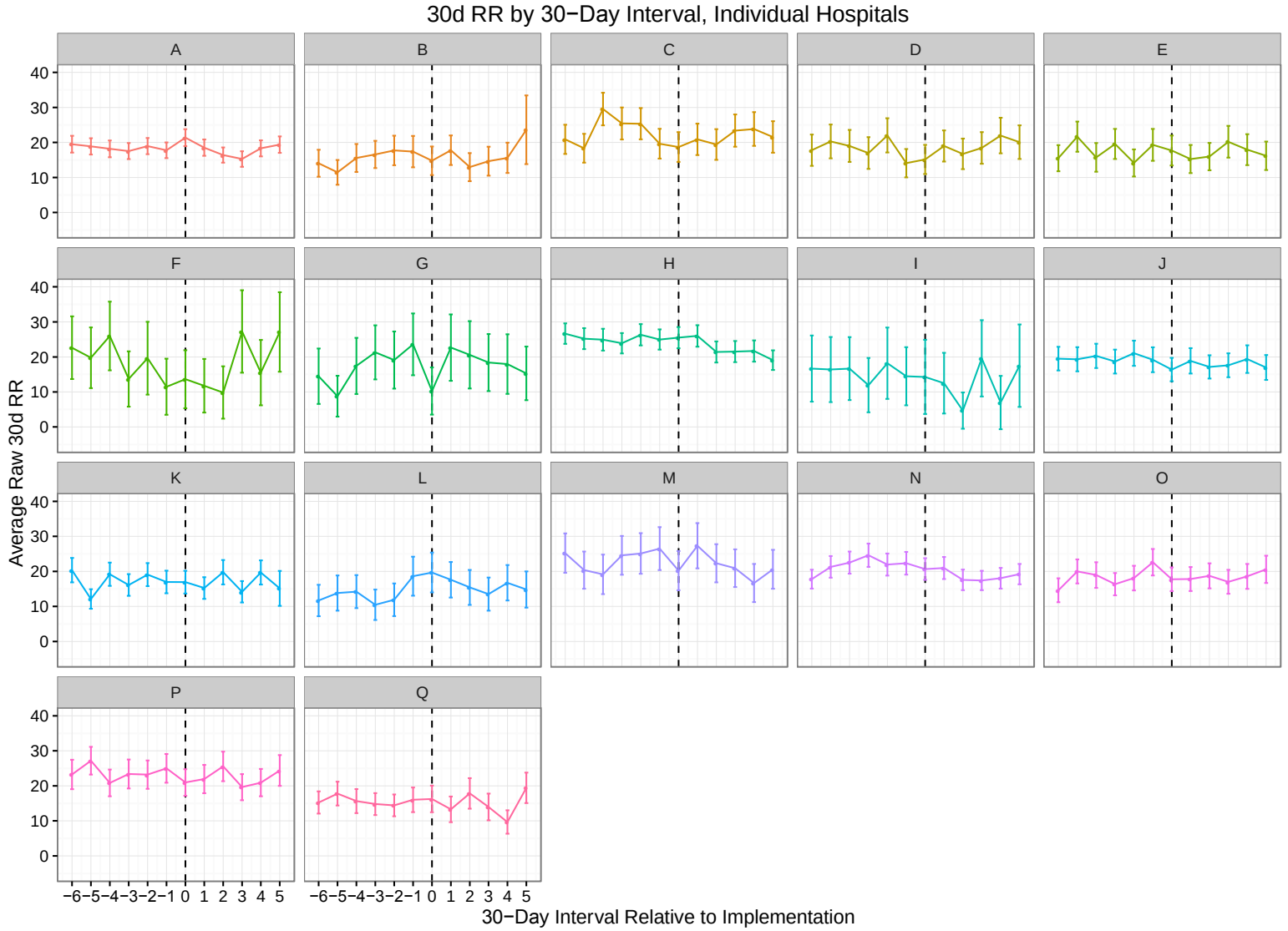
eFigure 4 shows adjusted odd ratios (OR) for the change in the rate of patient outcomes (30-day mortality, 30-day readmission rate and PSI-90 per 1,000 admissions rate) for an individual hospital in the same HRR as each of the study hospitals, matched to be the closest in bed size existing in the HRR, versus all other hospitals in the same hospital referral region in the post-EHR implementation period. The study hospital in the HRR was excluded in each of these analyses. All models were adjusted for patient and admission characteristics as specified in the statistical analysis section of the Methods and standard errors for 95% confidence intervals were estimated using robust variance estimators to account for clustering of admissions within hospitals.

eFigure 5: Unadjusted 30-day mortality rates relative to EHR implementation for individual hospitals



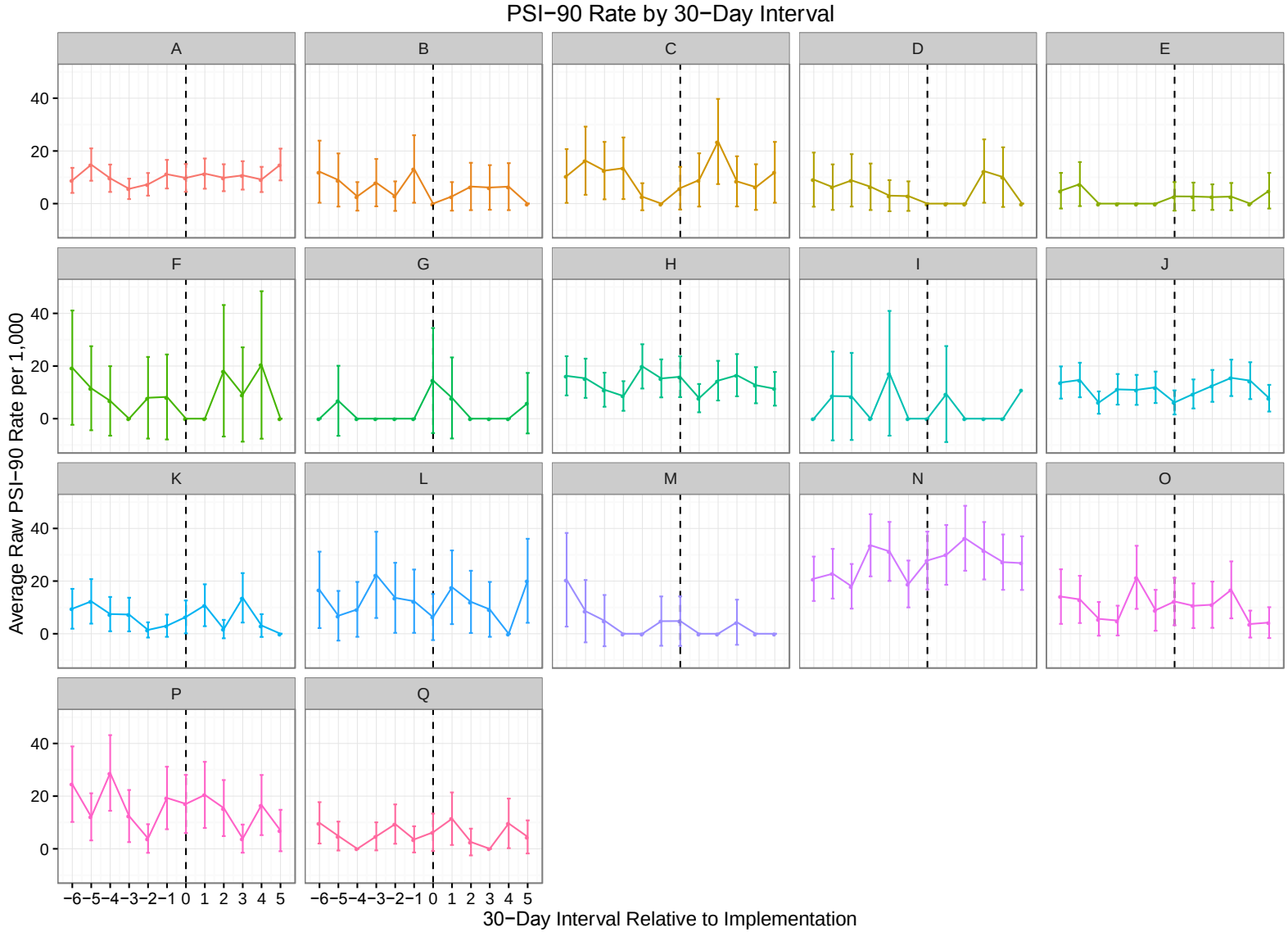
eFigure 5 shows trends in patient outcome rates for 30-day mortality in 30-day intervals relative to electronic medical record (EHR) implementation for each study hospital individually. Hospitals were randomly assigned letters to labels the graphs. 95% confidence intervals are shown for all unadjusted estimates, assuming a normal distribution of rates given the large sample size of admissions.

eFigure 6: Unadjusted 30-day readmission rates relative to EHR implementation for individual hospitals



eFigure 6 shows trends in patient outcome rates for 30-day readmission rates ("RR") in 30-day intervals relative to electronic medical record (EHR) implementation for each study hospital individually. Hospitals were randomly assigned letters to labels the graphs. 95% confidence intervals are shown for all unadjusted estimates, assuming a normal distribution of rates given the large sample size of admissions.

eFigure 7: Unadjusted PSI-90 event rates relative to EHR implementation for individual hospitals



eFigure 7 shows trends in patient outcome rates per 1,000 admissions for the Patient Safety for Selected Indicators (PSI)-90 composite measure in 30-day intervals relative to electronic medical record (EHR) implementation for each study hospital individually. Hospitals were randomly assigned letters to labels the graphs. 95% confidence intervals are shown for all unadjusted estimates, assuming a normal distribution of rates given the large sample size of admissions.